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(54) **METHOD AS WELL AS SYSTEM FOR PREDICTIVE MAINTENANCE OF AN AMPLIFIER MODULE**

(57) A method for performing predictive maintenance of an amplifier module (12) is described. At least one parameter of at least one amplifier module (12) is acquired via a measurement data acquisition unit (18). The

at least one parameter acquired is analyzed via a measurement data analyzing unit (20) so as to predict the probability and/or time of default of the at least one amplifier module (12). Further, a system (10) is described.

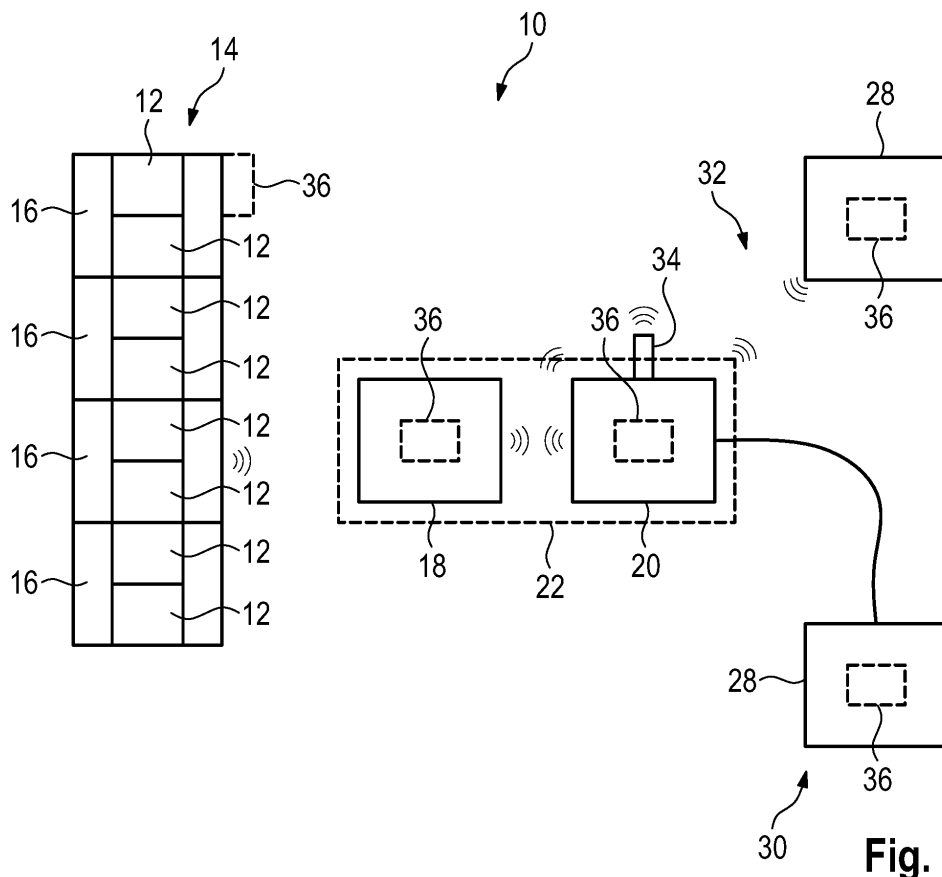


Fig. 1

Description

[0001] The invention relates to a method for performing predictive maintenance of an amplifier module. Further, the invention relates to a system for predictive maintenance of an amplifier module.

[0002] Amplifier modules are generally used for amplifying a signal received, for instance the power, the time-varying voltage or rather the current of the signal received. For this purpose, the respective amplifier module typically comprises a transistor being a component of the amplifier module. The amplifier module itself may be part of a superior amplifier system that comprises several amplifier modules or rather amplifier devices housing several amplifier modules. Each of the amplifier modules or rather amplifier devices comprise electrical circuits with components used for amplifying the respective signal processed.

[0003] Thus, each component of the amplifier module(s) may degrade over time until the respective component and, therefore, the amplifier module comprising the respective component fails. The default or failure results in a downtime of the amplifier module.

[0004] Typically, the user of the amplifier module or rather the superior amplifier system reacts on the occurring default detected by ordering the respective spare part that should replace the failed one of the amplifier module. However, this yields in a relative long downtime of the amplifier module or rather the superior amplifier system since the new component, namely the spare part, replacing the fault one has to be shipped to the user of the amplifier module or rather the superior amplifier system.

[0005] Accordingly, there is a need for a possibility to reduce the downtime of an amplifier module or rather a superior amplifier system in a cost-efficient and simple manner.

[0006] The invention provides a method for performing predictive maintenance of an amplifier module, with the following steps:

- acquiring at least one parameter of at least one amplifier module via a measurement data acquisition unit, and
- analyzing the at least one parameter acquired via a measurement data analyzing unit so as to predict the probability and/or time of default of the at least one amplifier module.

[0007] Further, the invention provides a system for predictive maintenance of an amplifier module, comprising at least one measurement data acquisition unit, at least one measurement data analyzing unit as well as at least one amplifier module, wherein the at least one measurement data acquisition unit and the at least one measurement data analyzing unit are configured to communicate with each other, wherein the at least one measurement

data acquisition unit is configured to acquire at least one parameter of the at least one amplifier module, and wherein the at least one measurement data analyzing unit is configured to receive and to analyze the at least one parameter acquired so as to predict the probability and/or time of default of the at least one amplifier module.

[0008] Accordingly, the downtime of the amplifier module or rather the downtime of a superior amplifier system comprising the at least one amplifier module can be minimized since a user of the respective amplifier module is enabled to act proactively instead of reacting on a failure that has already occurred. The invention ensures that the probability and/or time of default of the at least one amplifier module can be predicted by taking at least one parameter of the amplifier module into account that has been acquired previously so that a predictive maintenance for the amplifier module is provided.

[0009] For instance, the at least one amplifier module may be configured to communicate with the at least one measurement data acquisition unit so as to transmit the at least one parameter. Thus, the measurement data acquisition unit receives the at least one parameter that may be actively transmitted to the measurement data acquisition unit by the amplifier module. For instance, a communication according to message queuing telemetry transport (MQTT) protocol is used.

[0010] Furthermore, the respective parameter may only be transmitted by the amplifier module provided that its value has changed. This reduces the power consumption as well as the required computational power significantly.

[0011] In fact, components of the amplifier module or the amplifier module is under observation prior to the failure.

[0012] According to an aspect, the at least one parameter is assigned to the operating hours of the amplifier module. Thus, the operating hours of the amplifier module may be taken into account in order to predict the probability and/or time of default of the at least one amplifier module. For instance, a model may be used that predicts the probability and/or time of default by taking the actual operating hours of the amplifier module into account. Alternatively or additionally, a look-up table based on stored empirical data may be used for predicting the probability and/or time of default based on the operating hours.

[0013] According to another aspect, the at least one parameter is assigned to a temperature of the amplifier module in combination with another parameter of the at least one amplifier module. The other parameter may correspond to the operating hours of the amplifier module so that the temperature of the amplifier module is taken into account in combination with the operating hours of the amplifier module. Thus, the probability and/or time of default may be predicted due to a temperature behavior being characteristically for the actual operating hours of the amplifier module.

[0014] Moreover, the other parameter may correspond

to a certain operation mode of the amplifier module or another parameter of the amplifier module that has been acquired. Thus, a temperature rise in a certain operation mode may be analyzed so as to predict the probability and/or time of default.

[0015] Furthermore, the at least one parameter may be assigned to a transistor parameter, namely a parameter of the transistor being a component of the amplifier module. The transistor parameter may be an input level, a drain current and/or a gate current, in particular wherein the gate current is a common gate current of the amplifier module. The respective transistor parameter corresponds to a parameter that is directly assigned to the transistor of the amplifier module. The behavior of the respective transistor parameter may be acquired and analyzed appropriately for predicting the probability and/or time of default.

[0016] Generally, several parameters of the at least one amplifier module may be taken into account simultaneously so as to increase the accuracy of the prediction. In fact, the prediction is based on more information provided that several parameters are acquired and analyzed simultaneously.

[0017] According to an aspect, the time dependent behavior of the at least one parameter is analyzed. Thus, an increase or rather a decrease over time of the respective parameter can be identified which may indicate an upcoming default of the at least one amplifier module within the next months.

[0018] For instance, an increasing gate current (over time) indicates an upcoming failure or rather default of an associated transistor of the amplifier module within the next two to three months. In fact, the gate current is substantially zero in the delivery state of the amplifier module so that the value of the gate current can be used as an indication of an upcoming failure or default.

[0019] Furthermore, an increasing drain current of a transistor or rather an increasing drain current of the amplifier module may indicate a deterioration or rather failure of a respective component located downstream of the transistor or rather the amplifier module, for instance a (high frequency or rather radio frequency) connection, a cable or a combiner.

[0020] Particularly, a brazing solder disappears over time in case of high powers processed by the amplifier module, for instance high frequency signals having a power above 2 kW.

[0021] Moreover, a high input level, namely between the nominal input level and the maximum input level, in combination with a short-term gate current may indicate a high deterioration of a transistor yielding in a failure within the next two to six months.

[0022] Furthermore, the at least one parameter may be compared with a comparison parameter being of the same type, in particular wherein the comparison parameter is acquired from another amplifier module and/or wherein the comparison parameter is a previously acquired parameter. Thus, the actually acquired parameter

is compared with a previously acquired one so that a historical behavior or rather a trend can be analyzed appropriately. In case of high deviations, a critical behavior of the respective component may be existent.

[0023] Further, the actually acquired parameter may be compared with a comparison parameter derived from another amplifier module that may be located at a comparable position so that substantially the same values are expected due to the comparable positions. Deviations that occur during the comparison may yield an upcoming default.

[0024] For instance, drain currents between amplifier modules or rather transistors, namely components of the amplifier module(s), are acquired and compared with each other. Deviations higher than 20% obtained by the comparison may indicate that the component or rather amplifier module having the higher drain current will probably fail within the upcoming four to five months.

[0025] According to another aspect, a notification is output when the analysis yields an upcoming default, in particular wherein the notification is displayed on a display. Thus, the user of the respective system is informed proactively once a probably upcoming default has been detected by the analysis. Therefore, the user may act proactively and already place an order for the respective component, namely a spare part, used for replacing the prone one.

[0026] Moreover, the order may be placed automatically by the system wherein the user is informed about the order, for instance via the display.

[0027] For instance, the notification is output by the amplifier module itself, the measurement data acquisition unit, the measurement data analyzing unit and/or an external device. Accordingly, the amplifier module, the measurement data acquisition unit and/or the measurement data analyzing unit may comprise the display. Furthermore, the information may be accessed by the external device or rather transmitted to the external device.

[0028] Put another way, the at least one measurement data analyzing unit, the amplifier module, the measurement data acquisition unit and/or an external device may be configured to output a notification indicating the predictive probability and/or time of default of the amplifier module when the analysis yields an upcoming default. The respective component of the system may comprise a display provided that the notification is output graphically via the display.

[0029] In fact, the measurement data analyzing unit may communicate with the measurement data acquisition unit and/or the amplifier module itself so that the information with regard to the upcoming default is transmitted to the respective component of the system so that this component may display or rather output the notification.

[0030] According to another aspect, the at least one parameter acquired and/or the analysis result is transmitted by telemetry and/or wherein the at least one parameter acquired and/or the analysis result is accessed

via a web interface. The at least one parameter acquired may be transmitted to the measurement data acquisition unit, for instance by using a communication according to the MQTT protocol. Thus, telemetry data may be communicated between the amplifier module or rather the superior amplifier system and the measurement data acquisition unit in an automatic manner without any manual input. The transmission by telemetry may correspond to communicating via short message services (SMS) or electronic mail (e-mail). In a similar manner, the analysis result obtained by the at least one measurement data analyzing unit may be transmitted by telemetry.

[0031] The analysis result corresponds to the predicted probability and/or time of default of the at least one amplifier module.

[0032] Hence, this information may be output by an external device provided that the information is accessed via the web interface or rather the information is transmitted by telemetry. In addition or alternatively, the information is output at the amplifier module itself, the measurement data acquisition unit and/or the measurement data analyzing unit.

[0033] Furthermore, the at least one parameter acquired and/or the analysis result may be accessed via a web interface so that the respective information may be gathered via a smartphone, a mobile device, a tablet or rather a notebook.

[0034] Generally, the respective information may be submitted via the internet. Hence, the information may be forwarded to the manufacturer of the amplifier module via the internet.

[0035] The communication via the internet may be done via a satellite communication using telecommunication standards like long term evolution (LTE) or other telecommunication standards such as the global system for mobile communication (GSM).

[0036] A respective universal serial bus (USB) stick may be used for communication purposes. Therefore, the system may comprise a universal serial bus (USB) stick that is assigned to at least one of the amplifier module, the measurement data acquisition unit and the measurement data analyzing unit.

[0037] In addition, the measurement data acquisition unit and the measurement data analyzing unit may be integrated in a common device. The common device may relate to a single box that may comprise a single-board computer, an uninterruptable power supply (UPS) wherein the single-board computer may comprise at least one communication interface so that the common device is configured to communicate with the amplifier module.

[0038] Alternatively or additionally, a web interface is provided via which the at least one parameter acquired and/or the analysis result can be accessed, in particular from remote.

[0039] Alternatively or additionally, a telemetry system is provided so that the at least one parameter acquired and/or the analysis result can be transmitted (automatically), in particular to remotely located components of

the system.

[0040] In general, the amplifier module may be assigned to a measurement amplifier, a power amplifier, a broadband amplifier, a low-noise amplifier, a pulse amplifier, and/or an amplifier device.

[0041] Generally, the respective communication may be wireless and/or wired.

[0042] Further aspects and advantages of the claimed subject matter will become more readily appreciated as the same become better understood by reference to the following description, when taken in conjunction with the accompanying drawings. In the drawings:

- Figure 1 schematically shows an overview of a system according to the invention,
- Figure 2 schematically shows a common device comprising the at least one measurement data acquisition unit as well as the at least one measurement data analyzing unit, and
- Figure 3 schematically shows an overview illustrating a method according to the invention.

[0043] In Figure 1, a system 10 for predictive maintenance of an amplifier module 12 is shown. The amplifier module 12 is part of a superior amplifier system 14 that comprises several amplifier devices 16 each having several amplifier modules 12.

[0044] The amplifier modules 12 or rather the amplifier devices 16 may be installed in a rack or rather a cabinet as schematically shown in Figure 1.

[0045] In addition, the system 10 comprises a measurement data acquisition unit 18 that is configured to communicate with the at least one amplifier module 12 so that at least one parameter of the amplifier module 12 can be acquired. For instance, the amplifier module 12 and the at least one measurement data acquisition unit 18 may communicate with each other via a communication according to the message queuing telemetry transport (MQTT) protocol so that telemetry data of the amplifier module 12 is transmitted to the measurement data acquisition unit 18 in an automatic manner. In fact, the parameter is only transmitted in case that the value of the parameter changes so that the data exchange is minimized.

[0046] Furthermore, the system 10 comprises at least one measurement data analyzing unit 20 that communicates with the measurement data acquisition unit 18 so as to receive the parameter acquired.

[0047] The at least one measurement data analyzing unit 20 is configured to receive the parameter acquired and to analyze the at least one parameter acquired so as to predict the probability and/or time of default of the at least one amplifier module 12 based on the parameter acquired.

[0048] Hence, an expected downtime of the amplifier module 12 can be predicted resulting in a predictive main-

tenance for the amplifier module 12. This ensures that the user of the amplifier module 12 is enabled to act proactively instead of reacting on an already occurring failure.

[0049] Therefore, the downtime of the amplifier module 12 or rather the superior amplifier system 14 can be reduced significantly.

[0050] The measurement data acquisition unit 18 as well as the measurement data analyzing unit 20 may be established in a common device 22 as shown in Figure 2. Furthermore, the measurement data acquisition unit 18 as well as the measurement data analyzing unit 20 may be established in a common manner.

[0051] As shown in Figure 2, the common device 22 comprises a single-board computer 24 that may be configured to establish the measurement data acquisition unit 18 as well as the measurement data analyzing unit 20 simultaneously. In addition, an uninterruptible power supply 25 such as a battery is provided that is connected to the single-board computer 24.

[0052] The single-board computer 24 may further comprise a communication interface 26 so that the common device 22 is enabled to communicate with the at least one amplifier module 12 or rather the superior amplifier system 14 as well as external devices 28 such as a computer, a notebook, a mobile device, a tablet or rather a smartphone.

[0053] The common device 22 may have a housing 27 that houses the components mentioned above. The housing 27 ensures the required electromagnetic compatibility (EMC). In the shown embodiment, the housing 27 comprises a base part as well as a lid (not shown) that can be fixedly connected with the base part so as to close the space accommodating the single-board computer 24 and the uninterruptible power supply 25.

[0054] Furthermore, the system 10 may comprise a web interface 30 or rather a telemetry system 32 for establishing the communication, data exchange or rather data access between the respective components of the system 10.

[0055] For instance, a universal serial bus (USB) stick 34 may be provided being part of the system 10 wherein the universal serial bus stick 34 is assigned to one of the components of the system 10, for instance the common device 22, so as to establish a communication according to a telecommunication standard such as long term evolution (LTE) or global system for mobile communication (GSM).

[0056] The web interface 30 ensures that a user of the system 10 can access a certain component of the system 10 so as to retrieve the information desired, for instance the analysis result of the measurement data analyzing unit 20 or rather the acquired parameter by accessing the measurement data acquisition unit 18, the analyzing module 12 or the analyzing system 14 directly.

[0057] Furthermore, the respective information may be transmitted by using the telemetry system 32 or rather the communication established by the universal serial

bus stick 34.

[0058] Hence, the information may be transmitted to the manufacturer of the amplifier module 12 so that the component or rather the amplifier module 12 which is deemed to fail in the near future is ordered directly and automatically. This ensures that the spare part is provided once the amplifier module 12 fails so that the downtime can be reduced significantly.

[0059] The system 10 further comprises a display 36 that is used for displaying a notification indicating the predicted probability and/or time of default of the amplifier module 12 when the analysis yields an upcoming default.

[0060] The display 36 may be assigned to the at least one measurement data analyzing unit 20, the amplifier module 12 itself, the superior amplifier system 14 and/or the external device 28.

[0061] The respective notification may be output in another way instead of being displayed, for instance acoustically.

[0062] Generally, the external device 28 may comprise the measurement data analyzing unit 20 so that the data acquired is analyzed remotely. The external device 28 may be a computer configured to communicate with the measurement data acquisition unit 18.

[0063] Alternatively or additionally, the respective data is transmitted to the manufacturer of the amplifier module 12, a service provider or another authorized party via the internet or rather a telecommunication network, for instance the LTE/GSM network. For the communication via the telecommunication network, the respective stick 34 may be used.

[0064] The system 10 is generally configured to perform a method for performing predictive maintenance of the amplifier module 12 as will be described hereinafter with reference to Figure 3.

[0065] In a first step S1, at least one parameter of the at least one amplifier module 12 is acquired via the measurement data acquisition unit 18.

[0066] The parameter may be acquired by measuring the at least one parameter or rather by receiving the parameter which is transmitted by the amplifier module 12 in case of a changing value of the respective parameter. In fact, the parameter may be transmitted automatically without any manual input.

[0067] In a second step S2, the at least one parameter acquired is analyzed by the measurement data analyzing unit 20 so as to predict the probability and/or time of default of the at least one amplifier module 12 based on the information assigned to the at least one parameter obtained.

[0068] Once the analysis yields an upcoming failure, a notification is output in a third step S3 so as to inform the user of the system 10 with regard to the upcoming failure of the amplifier module 12 as well as the remaining time and/or the probability of the upcoming failure.

[0069] In a fourth step S4, the failure may be located. This means that a certain component of the complex amplifier module 12 is indicated which probably fails in the

near future. The respective location may be output, in particular displayed, so that the user gets informed appropriately.

[0070] For this purpose, a model of the respective amplifier module 12 may be provided wherein the respective components are shown. The components may be indicated by different colors according to their status.

[0071] Thus, a component that probably fails within the next months may be colored red so that the user knows which component has to be replaced in the near future.

[0072] In a fifth step S5, the system 10 may order automatically a respective spare part for the amplifier module 12 or rather the component thereof that may fail in the near future. This ensures that the respective spare part is on-site once the amplifier module 12 or rather the respective component thereof fails. The downtime of the amplifier module 12 can be reduced significantly.

[0073] As indicated above, the at least one parameter used for predictive maintenance may ensure that the upcoming failure or default of the amplifier module 12 is located.

[0074] For instance, the parameter may be assigned to at least one of the operating hours of the amplifier module 12, a temperature of the amplifier module 12 in combination with another parameter of the amplifier module 12, for instance the operating hours of the amplifier module 12, or rather a transistor parameter of the amplifier module 12.

[0075] The transistor parameter may correspond to an input level, a drain current and/or a gate current, in particular wherein the gate current is a common gate current of the amplifier module.

[0076] Accordingly, the amplifier module 12 itself is configured to automatically transmit the respective data related to the parameter. Alternatively or additionally, the measurement data acquisition unit 18 is configured to measure the respective parameter.

[0077] Hence, the measurement data acquisition unit 18 may comprise a sensor for sensing the parameter, namely a temperature sensor, a current sensor and/or a power sensor.

[0078] Moreover, the measurement data analyzing unit 20 receiving the acquired parameter may compare the parameter acquired with a comparison parameter so as to find a deviation which might indicate an upcoming default.

[0079] The comparison parameter can be a previously acquired value of the same parameter.

[0080] Alternatively or additionally, the comparison parameter may correspond to a parameter derived from another amplifier module that may be located at a comparable position.

[0081] Irrespective of the comparison parameter used, the time dependent behavior of the at least one parameter may be taken into account for predicting the probability and/or time of default of the at least one amplifier module 12.

[0082] For instance, an increasing gate current (over

time) may indicate that a failure or rather default of an associated transistor of the amplifier module 12 is probably within the next two to three months.

[0083] Moreover, an increasing drain current of a transistor of the amplifier module 12 or rather an increasing drain current of the amplifier module 12 may indicate a deterioration or failure of a respective component located downstream of the transistor or rather the amplifier module 12, for instance a (high frequency or rather radio frequency) connection, a cable or a combiner. For instance, a brazing solder used for the connection may disappear over time in case of high powers processed by the amplifier module 12.

[0084] Furthermore, a high input level, namely between the nominal input level and the maximum input level, in combination with a short-term gate current may indicate a high deterioration of a transistor yielding in a failure within the next two to six months.

Claims

1. A method for performing predictive maintenance of an amplifier module (12), with the following steps:
 - Acquiring at least one parameter of at least one amplifier module (12) via a measurement data acquisition unit (18), and
 - Analyzing the at least one parameter acquired via a measurement data analyzing unit (20) so as to predict the probability and/or time of default of the at least one amplifier module (12).
2. The method of claim 1, wherein the at least one parameter is assigned to the operating hours of the amplifier module (12).
3. The method of claim 1 or 2, wherein the at least one parameter is assigned to a temperature of the amplifier module (12) in combination with another parameter of the at least one amplifier module (12), in particular wherein the other parameter corresponds to the operating hours of the amplifier module (12).
4. The method of any of the preceding claims, wherein the at least one parameter is assigned to a transistor parameter such as an input level, a drain current and/or a gate current, in particular wherein the gate current is a common gate current of the amplifier module (12).
5. The method of any of the preceding claims, wherein the time dependent behavior of the at least one parameter is analyzed.
6. The method of any of the preceding claims, wherein the at least one parameter is compared with a comparison parameter being of the same type, in partic-

ular wherein the comparison parameter is acquired from another amplifier module and/or wherein the comparison parameter is a previously acquired parameter.

7. The method of any of the preceding claims, wherein a notification is output when the analysis yields an upcoming default, in particular wherein the notification is displayed on a display (36).
8. The method of claim 7, wherein the notification is output by the amplifier module (12) itself, the measurement data acquisition unit (18), the measurement data analyzing unit (20) and/or an external device (28).
9. The method of any of the preceding claims, wherein the at least one parameter acquired and/or the analysis result is transmitted by telemetry and/or wherein the at least one parameter acquired and/or the analysis result is accessed via a web interface (30).
10. A system (10) for predictive maintenance of an amplifier module (12), comprising at least one measurement data acquisition unit (18), at least one measurement data analyzing unit (20) as well as at least one amplifier module (12), wherein the at least one measurement data acquisition unit (18) and the at least one measurement data analyzing unit (20) are configured to communicate with each other, wherein the at least one measurement data acquisition unit (18) is configured to acquire at least one parameter of the at least one amplifier module (12), and wherein the at least one measurement data analyzing unit (20) is configured to receive and to analyze the at least one parameter acquired so as to predict the probability and/or time of default of the at least one amplifier module (12).
11. The system (10) of claim 10, wherein the at least one parameter is assigned to the operating hours of the amplifier module (12), a temperature value of the amplifier module (12) in combination with another parameter and/or a transistor parameter such as an input level, a drain current and/or a gate current, in particular wherein the gate current is a common gate current of the amplifier module (12).
12. The system (10) of claim 10 or 11, wherein the at least one measurement data analyzing unit (18) is configured to analyze the time dependent behavior of the at least one parameter.
13. The system (10) of any of claims 10 to 12, wherein the at least one measurement data analyzing unit (20) is configured to compare the at least one pa-

rameter with another parameter of the same type that is acquired from another amplifier module (12) and/or a previously acquired parameter.

14. The system (10) of any of claims 10 to 13, wherein the at least one measurement data analyzing unit (18), the measurement data acquisition unit (20), the amplifier module (12) and/or an external device (28) are/is configured to output a notification indicating the predicted probability and/or time of default of the amplifier module (12) when the analysis yields an upcoming default.
15. The system (10) of any of claims 10 to 14, wherein the measurement data acquisition unit (18) and the measurement data analyzing unit (20) are integrated in a common device (22) or wherein a web interface (30) and/or a telemetry system (32) are/is provided via which the at least one parameter acquired and/or the analysis result is transmitted and/or accessed.

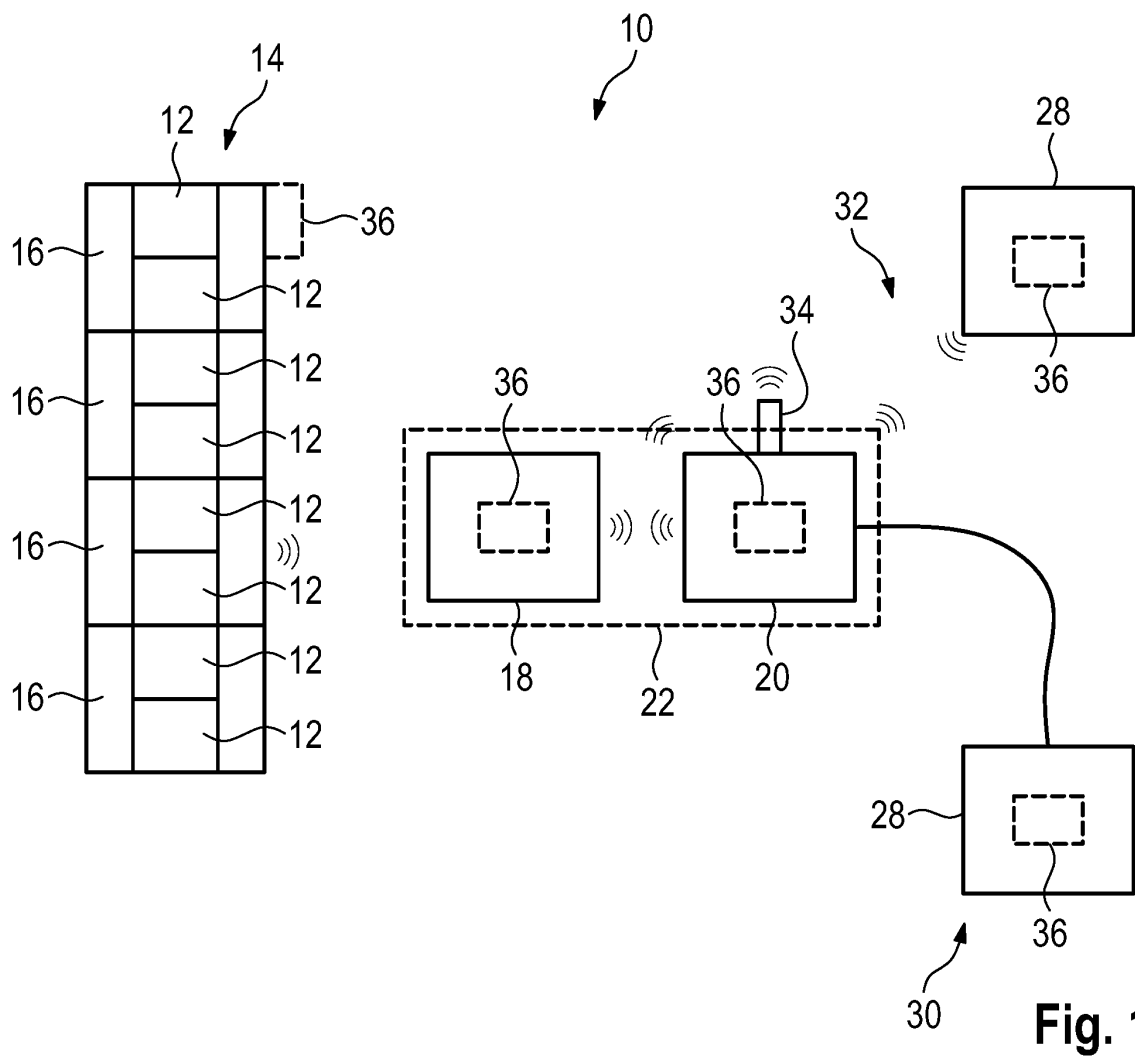


Fig. 1

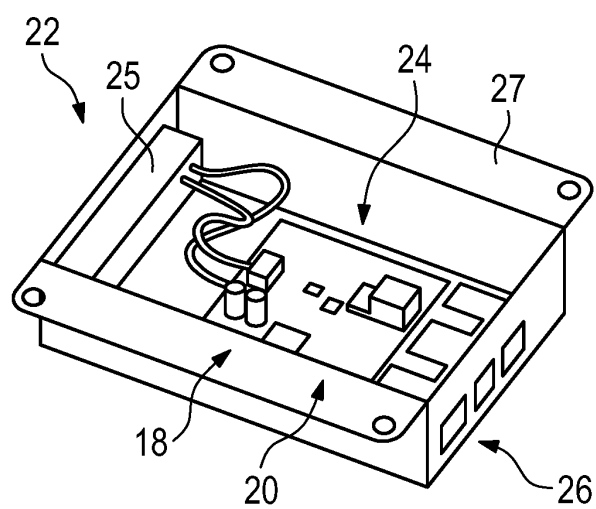


Fig. 2

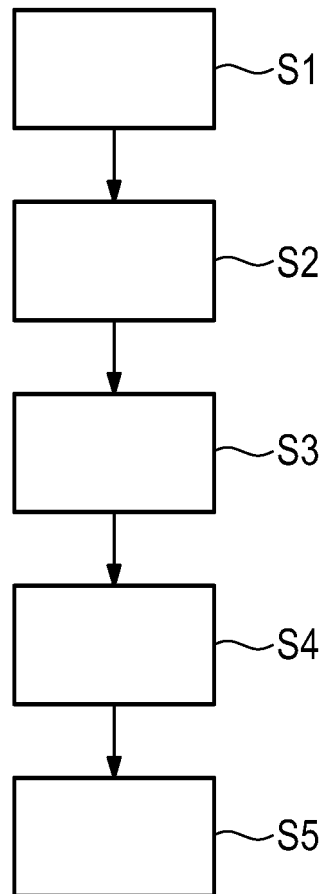


Fig. 3



EUROPEAN SEARCH REPORT

Application Number
EP 18 20 4941

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The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 10 April 2019	Examiner Agerbaek, Thomas
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EPO FORM 1503 03.82 (P04C01)

**ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.**

EP 18 20 4941

5 This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
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